# Effects of Temperature and Other Environmental Factors on *Notonecta undulata* Say
(Hemiptera: Notonectidae)

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*Notonecta undulata* Say is widely distributed throughout North America (Brooks and Kelton 1967, Bueno 1905). Exhaustive studies of external anatomy, life history and some briefer notes on the ecology and behavior of this aquatic insect have been made (Hungerford 1919, Clark 1928 and Essenburg 1915). This paper concerns the importance of temperature as a factor in this species' distribution as determined by both field and laboratory measurements.

## MATERIALS AND METHODS

Specimens were collected mainly from Lost Iake, B. C., a small bog pond rich with aquatic insects. About 15 adults per 15 gallon aquarium could be maintained without significant cannibalism if a surplus of fresh food was provided daily. Flour beetles, bark beetles, ants, corixids, aphids, *Daphnia* sp. and fry of the common guppy, *Lebistes reticulatus* Peters were supplied as prey. The aquaria were provided with sand, filters, aerators, heaters and lighted canopies. Water temperature was maintained at 25 ± 2°C, pH at 6.6 and water hardness at 25 ppm. Bunches of *Anacharis canadensis* Michx. were provided as sites for oviposition and protective cover. *Notonecta undulata* will oviposit on a wide variety of objects in captivity including the glass walls of aquaria, plastic filter boxes and rubber sink matting. It appears to prefer plants to these, however, probably because plants are easier to cling to. When eggs were oviposited on plants they could then be transferred without damage to an incubation aquarium.

In spring and summer, 1967, a survey was made of fresh water habitats in the Lower Fraser Valley, B. C., to determine where and under what conditions *N. undulata* was most abundant. Water temperature, pH, and hardness were measured and notes on the major flora and fauna recorded whenever this species was found.

A simple temperature preference apparatus, similar to that used by Omardeen (1957) for *Aedes aegypti* (L.) was set up in the laboratory under constant light. An aluminum trough filled with wet sand was

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placed with one end on a hot plate, the temperature of which could be controlled and the other end in an ice bath. An aluminum based glass trough (15 × 15 × 60 cm) was placed on top of the sand and filled to 1.5 cm with filtered aquarium water. This allowed free horizontal movement by the backswimmers, while limiting convection currents which occurred in deeper water. Temperature was measured by 8 thermometers suspended at equal intervals throughout the length of the apparatus. With this set-up a temperature gradient (eg. 15–20°C) could be established in 30 minutes by adjusting the control dial of the hot-plate.

Insects tested for temperature preference were 18 first instars, 4 fifth instars and 7 adults in 42, 33 and 65 trials respectively. Insects were introduced into the middle of the gradient apparatus and left approximately 5 minutes before their position was recorded. The difference in temperature between the two ends of the apparatus varied from 13.0 to 27.0°C (first instars), 7.5 to 10.0°C (fifth instars) and 4.0 to 5.0°C (adults). Counts of individuals at each temperature were made every 5 minutes after shifting the gradient several degrees for each trial; no 2 gradients were the same.

The upper limit of water temperature in which *N. undulata* can survive was determined using large glass beakers (3000 ml) heated with standard aquarium heaters and gently aerated to ensure uniform water temperature. The number of survivors at each temperature was noted hourly, for nine hours. Death was verified by returning an insect to 25°C to check for revival. Temperatures and number of adults tested were 34, 35, 36, 37, 38, 39, and 40°C and 6, 22, 13, 17, 20, and 19 respectively.

## Results

Temperature Preference.—The mean preferred temperatures for first and fifth instar nymphs and adults were 27.5, 27.1 and 27.0°C respectively (Fig. 1). None of the insects tested ventured into water exceeding 39°C and only one was found at 16°C, the lowest temperature recorded. As the temperature of the 'hot' end was slowly increased or decreased (2–5°C per 5 minutes) the majority of the individuals (especially first instar nymphs) grouped in the optimum area would, almost as a unit, shift their position to the water temperature at which they had just been.

Upper Limits of Temperature.—All six adults tested at 34°C survived over 9 hours (Fig. 2). Mortality slowly increased above this temperature, while the premortality exposure time decreased. At 9 hours, percent mortality varied almost directly with temperature.

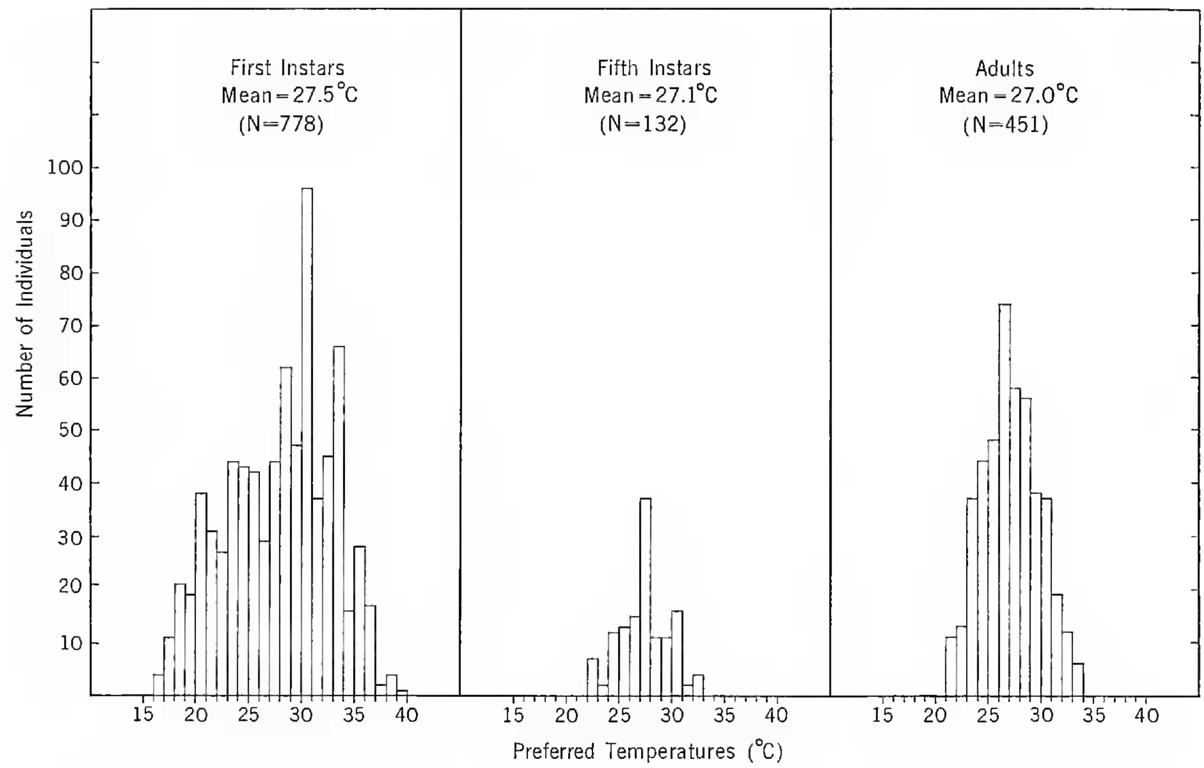


FIG. 1. Temperature preference of *N. undulata* nymphs and adults in a temperature gradient.

At high temperatures the backswimmers repeatedly tried to escape. They swam excitedly below the surface, climbed up the air-line out of the water, or swam dorsal side-up on the surface. The beakers were covered with paper towelling to prevent any of the insects from escaping.

DISTRIBUTION AND HABITAT CONDITIONS.—The wide variety of aquatic habitats in which *N. undulata* exists and reproduces is illustrated by 4 examples. In early May it was found in a swimming pool (Coquitlam, B. C.) with a high chlorine content (approx. 40 ppm) relative to natural waters. The water temperature was 10.0°C, water hardness 28 ppm (very soft) and the pH 6.0. Vegetation was limited to a variety of freshwater algae (e.g. *Nostoc* and diatoms). Two species of dytiscids and several gerrids were abundant in the same pool. All were observed feeding on terrestrial insects trapped in the surface film. Mating and oviposition of *N. undulata* began in mid-May. First instars were observed in this pool when the water was 17°–20°C in later May.

Lost Lake (B. C.), a bog pond 150 × 200 m, contained hundreds of backswimmers in various instars throughout May, June and July. *N. undulata* was the predominant backswimmer but a *Buenoa* sp. was relatively numerous for about three weeks. All the major orders of aquatic insects were present. The water was very soft (30 ppm), the pH 6.0, and

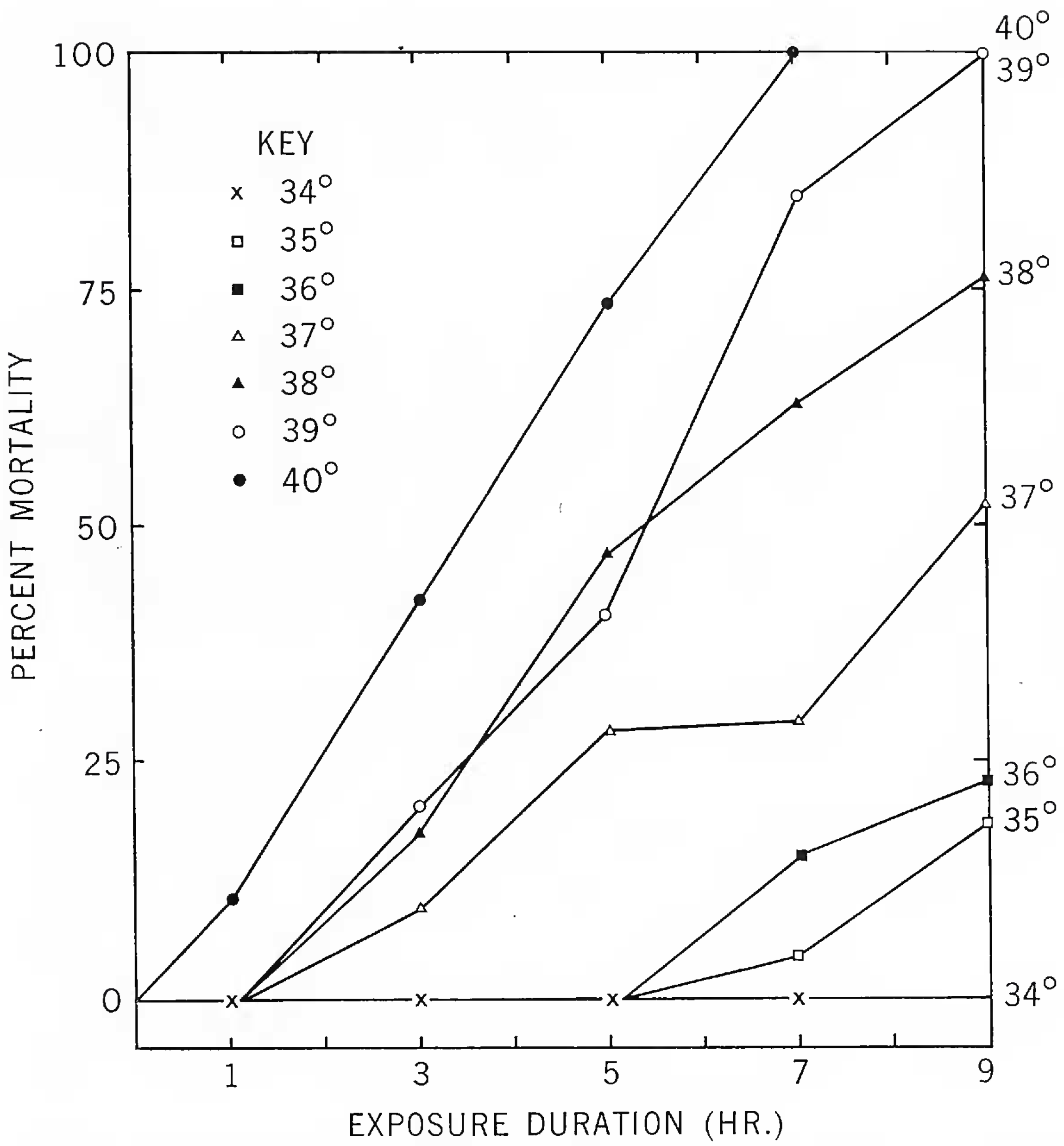


FIG. 2. Effect of exposure to high temperatures on the survival of *N. undulata* adults.

when the air temperature was 22.0°C the shallow water near the shore inhabited by the *N. undulata* was 24.0°C. A varied and luxurient array of aquatic plants grew around the shallow margins.

Deer Lake (Burnaby, B. C.) contained relatively few *N. undulata.* Other aquatic insects (mainly corixids) were present but not in large numbers. When the air temperature was 29.0°C the surface water was 21.0°C, water hardness was 34 ppm; pH was 7.1. Food was abundant at this time as evidenced by large plankton hauls of *Daphnia* sp. Vegetation also was plentiful.

Several hundred *N. undulata* in the later instars were found in an excavation pond (10 m$^2$ and 0–25 cm deep), and a shallow drainage ditch leading from it on Burnaby Mountain, B. C., during late July. Also found in the pond were several hundred tadpoles, several dytiscids and a few gerrids. When the air temperature was 28.0°C the pond was 32.5°C and the ditch 29.0°C. Both pond and ditch had a pH of 7.0 and water hardness of 220 ppm (very hard). Only a few emergent plants were present.

## DISCUSSION

Laboratory trials and field measurements indicate that *N. undulata* is able to sustain itself over a wide range of water temperature (4–32°C), water hardness (28–220 ppm) and pH (6.0–7.1). The temperature range in which mating and oviposition can occur appears narrower, 10–32°C (Hungerford 1919). Four generations per year can be reared in laboratory aquaria kept at 25°C but there are usually only two generations per year in Southern British Columbia habitats—one in late spring and the other in late summer.

Although *N. undulata* can withstand relatively high temperatures for short periods of time (Fig. 2), 34°C is the highest temperature at which no mortality occurred in the 9 hour trials. Exposure for this period would not normally occur in backswimmer habitats. Above 34°C the survivorship decreased rapidly. These findings are consistent with the observation that at a cuticle temperature between 32–34°C there is a sharp increase in water evaporation rate in *Notonecta* sp. This is probably because of changes in molecular orientation of the cuticular lipid monolayer and in nature would result in lethal water uptake (Beament 1961). In nature *N. undulata* will attempt to escape from water at 34°C. When the water in the excavation pool, mentioned above, reached 32.5°C many adults were observed swimming rapidly at the surface and flying away. Habitats in S. W. British Columbia, would seldom reach 34°C.

The ability to reproduce over a fairly wide range of temperatures and to withstand high temperatures during the reproductive season would allow *N. undulata* to inhabit small, sometimes temporary, bodies of water where the temperature may rise far above the preference level and vary considerably in a short time.

*Notonecta undulata* often occurs in the same interior B. C. lakes as *Notonecta kirbyi* Hungerford which lives in waters with a pH of 7.0 to 9.2 (Scudder 1965). Thus, *N. undulata*, can probably live and reproduce in water with a pH of 6.0–9.2. It would appear then that pH, as well as water hardness, has little direct effect on the habitat preference of *N. undulata*. These factors may indirectly influence prey abundance and protective cover by determining the abundance and species composition of shore plants.

Clark (1928) summarized the characteristics of an optimum habitat for *N. undulata* in the Winnipeg region: a pool teeming with aquatic life, vegetation, no current, ample sunlight and a certain amount of water not covered by algae. Lost Lake (B. C.), which fits this description very well, supported the largest population of *N. undulata* in the survey, yet the excavation pool had almost as dense a population but with very little vegetation. However, the presence of *N. undulata* in almost all types of relatively static waters in S. W. British Columbia is evidence of its tolerance of a wide range of environmental characteristics.

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